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(19)(CA) **APPLICATION FOR CANADIAN PATENT** (12)

(54) Hydrophobic Extracted Neem Oil - a Novel Insecticide and Fungicide

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ABSTRACT

A novel insecticide and foliar fungicide derived from a neem seed extract comprising neem oil which is substantially free of azadirachtin and salannin, said neem oil being prepared by extracting dried, coarsely ground neem seeds with a non-polar, hydrophobic solvent to obtain a neem oil extract, and then removing the solvent to obtain the neem oil. These neem oil pesticides exhibit the ability to repel insects from plant surfaces, prevent fungal growth, and kill insect and fungal pests at various life stages.

Background of the Invention

Field of the Invention

This invention relates to novel pesticide compositions derived from neem seeds, and more specifically to a novel insecticide and foliar fungicide comprising a hydrophobic-solvent extracted neem oil. These neem oil pesticides exhibit the ability to repel insects from plant surfaces, prevent fungal growth and kill insect and fungal pests at various life stages.

Description of Prior Art

The neem tree, a tropical evergreen, has been used for centuries as a source of pesticides to which insects have not developed a resistance. Various neem seed extracts, particularly the ones containing the hydrophilic, tetranortriterpenoid azadirachtin, are known to influence the feeding behavior, metamorphosis (insect growth regulating [IGR] effect), fecundity, and fitness of numerous insect species belonging to various orders.

It is known that neem oil, containing azadirachtin, may be mechanically pressed from neem seeds in the cold by using oil presses or may be extracted using alcohols or other solvents using Soxhlet apparatus. Small amounts of neem oil can be obtained by kneading neem seed powder by hand after adding some water (Schmutterer & Helip 1948). Thus the term 'neem oil' has been used to describe a variety of materials containing a mixture of both hydrophilic and hydrophobic extractables. The variety of extraction methods and resultant variety in composition of neem oil has led to great confusion as to the true properties of "neem oil". Khan and Wassilew (1986) tested

the effect of their "neem oil" (prepared by aqueous extraction of neem kernels) on 14 common fungi, including Trichophytonrubrum, T. violaceus, T. concentricus, T. mentagrophytes, Epidermophyton floccosum, Microsporum citaneum, Scrophulariopsis brevicaulis, Geotrichum candidum and Fusarium sp and found that it did not inhibit fungal growth and, in fact, the neem oil itself actually contained several species of growing fungi. Yet an anonymous article (Anon 1986) reported that "10% Neem oil diluted from its emulsifiable concentrate formulation" completely inhibited several species of fungi such as Aspergillus niger, Fusarium moniliforme, Macrophomina phaseolina and Drechslera rostrata. However, the specific details of this formulation were not provided.

Similarly, there are discrepencies in the literature as to the use of neem oil to control insects. Schmutterer and Hellpap (1986) showed that aqueous neem seed extracts are significantly superior to neem oil in repelling leaf mites (Scrobipalpa ergasina), leaf roller (Phycita melogenu) and leaf hopper (Jacobiella facialna). While Mansour et al. (1986) report that the pentane extract of neem seeds was much more effective at controlling the spider mite Tetranychus cinnabarinus than were ethanol or methanol extracts, but surprisingly, the pentane extract was less effective at controlling the mite, Phytoseiulus persimilis than were the ethanol or methanol extracts.

Yamasaki, et al showed that the tetranortriterpenoid, salannin, can be isolated from crude plant extracts, obtained from Indian neem seeds which are known to be high in salannin content, using hexane. The biological activity of the salannin extract is reported to be feeding deterency and growth inhibition when applied to chewing insects such as beetles and caterpillers.

This invention clarifies the discrepancies in the prior art and provides a novel neem oil extract that is substantially free of azadirachtin and salannin and yet is effective as both a foliar fungicide and an insecticide.

It has now been discovered that under the process of this invention, a non-polar hydrophobic-solvent extracted neem oil, substantially free of azadirachtin and salannin, possesses the ability to repel insects from plant surfaces, kill insects at various life stages in particular the egg and larval stages, and control the growth of serious fungal pathogens. This dual activity as both an insecticide and fungicide in the absence of azadirachtin is novel and unique.

The insecticide and fungicidal activities of hydrophobicly extracted neem oil is unique and unexpected in view of the absence of any known active ingredients.

Summary of the Invention

It is an object of this invention to provide a novel pesticide that repels insect pests from plant surfaces and kills insects at various life stages in particular the egg and larval stages, and controls the growth of various fungi.

Another object of this invention is to provide a natural pesticide formulation derived from neem seed extracts for the protection of plants from various insect or fungal pests.

In accordance with the present invention, there have been provided certain novel pesticide formulations derived from neem seed extracts, said formulations comprising

non-polar hydrophobic-solvent extracted neem oil fractions, that are substantially free of azadirachtin and salannin.

Detailed Description

Some active ingredients of the seeds and leaves of the tropical neem tree, Azadirachtin indica, particularly the tetranortriterpenoids azadirachtin and salannin, are known for their potent pesticidal activities. The present invention is directed to various pesticide formulations prepared from neem oil which are substantially free of azadirachtin and salannin, and yet said formulations possess the ability to repel insect pests from plant surfaces, kill insect pests at various life stages in particular the egg and larval stage, and control fungal pathogens.

Neem seeds can be quite variable in size, shape and composition. Seeds from around the world can be as small and round as a pea and as large and long as a bean. Neem seeds consist of two parts, a shell that does not contain oil or pesticidal activity and the kernal which contains oil and azadirachtin. However, the composition of seeds collected from throughout the world varies considerably as shown in Table A. In particular we have found that oil derived from neem trees with high azadirachtin concentration is both insecticidal and fungicidal.

Table A

Seeds Source	% Kernal in Seed	% Volatile	Oil %	AZAD mg/gsk*
Senegal (Pout)	54	[illegible]	[illegible]	6.6
India (Punjab)	55	5.8	36	1.6
Togo (Atkpame)	57	7.3	[illegible]	4.5
Haiti (Arcahie)	51	12.0	19	2.7
Ghana (Bawk)	57	6.4	14	3.9

*gsk = gram seed kernel

The pesticide formulations of this invention are prepared from neem oil which has been extracted from, dried, coarsely ground neem seeds with a suitable non-polar, hydrophobic solvent. In accordance with this invention, dried neem seeds, typically containing about 5 to 15% water, are coarsely ground to about 5 mesh. The ground neem seeds are then extracted with a non-polar hydrophobic solvent to remove neem oil. It is preferred to use a significant excess of solvent (3 to 1 w/w) to obtain good yields. The solvent must be suitably hydrophobic to prevent excess water from contaminating the product. Water in the extract will cause azadirachtin to be extracted from the seeds and result in hydrolysis of the extract. After extraction, the solvent is removed from the extract by low temperature evaporation, preferably by vacuum evaporation to yield the neem oil product.

Final pesticide formulations, in accordance with this invention, can be prepared by diluting the neem oil with about 5 to 50% preferably 5 to 20% and most preferably 7 to 15% by volume emulsifying surfactant and may optionally contain 0-1% PABA. Suitable emulsifying surfactants include sorbitan esters, ethoxylated and propoxylated mono

and diglycerides, acetylated mono- or diglycerides, lactylated mono- or diglycerides, citric acid esters of mono- or diglycerides, sugar esters, polysorbates, poly-glycerol esters, and the like, and mixtures thereof. The preferred emulsifying surfactants are the polyoxyethylene derivatives of fatty acid partial esters of sorbital anhydrides which are sold under the name Tween 20, Tween 40, Tween 60 and Tween 80. Prior to final application, these pesticide formulations are typically diluted with water.

For foliar application it has been observed that rates of 0.1 to 10%, preferably 0.25 to 3% neem oil diluted in water is effective for control of insect pests and fungal diseases without unacceptable plant damage. Neem oil may also be used at various dilutions to control various pest and disease problems on turf, horticultural and agricultural crops as well as stored fruits and vegetables. The neem oil formulations have been shown to be effective at controlling such pests as Colorado Potato Beetle, Diamond Backed Moth, Whitefly, Mealy bug, Aphids, Hornworm, Lacebug, mites, fleas, ticks, mosquitoes and flies and the like. They are also effective at controlling fungi such as mildews, rusts, dollar spot, brown patch, black spots, botrytis, and the like. Furthermore, the neem oil can be used to control parasitic pests on mammals such as lice, ticks, scabies, as well as eczema and dermatitus.

Suitable non-polar, hydrophobic solvents for use in extracting the neem oil from the ground neem seeds will include those solvents having high neem oil solubility and substantially no azadirachtin or water solubility. The preferred non-polar solvents include, but are not limited

to, aliphatic hydrocarbons and halogenated aliphatic hydrocarbons such as pentane, hexane, heptane, octane, nonane, decane, isooctane, chloropentane, chlorohexane, and the like, and their isomers; petroleum distillates, petroleum ether, and the like; aromatics and substituted aromatics such as benzene, toluene, chlorobenzene, benzaldehyde, xylenes, and the like; and mixtures thereof. Various other non-polar solvents having the above characteristics are well known to those skilled in the art, and the choice of a particular solvent is not per se critical to the invention, provided that it is substantially azadirachtin-insoluble and neem oil has a high degree of solubility therein.

Without further elaboration, it is believed that one skilled in the art, using the preceding detailed description can utilize the present invention to its fullest extent. The principles, preferred embodiments and modes of operation of the present invention have been described in the foregoing specification. The following examples are provided to illustrate the invention in accordance with the principles of this invention, but are not to be construed as limiting the invention in any way except as indicated in the appended claims. Variations and changes may be made by those skilled in the art without departing from the spirit of the invention. All parts and percentages are by weight unless otherwise indicated.

Example 1

This example illustrates the effectiveness of the non-polar, hydrophobic-solvent extracted neem oil formulations of this invention on newly laid or

near-to-hatch greenhouse whitefly (Trialeurodes vaporariorum) eggs. Eighty (80) kgs of dried defatted neem seeds from Africa were ground in a cutting mill to about 10 mesh. The ground seeds were added to a 300 gallon agitated vessel together with 140 gallons (459 kgs) of hexane and agitated for 18 hours. The extracted seeds were then separated from the hexane-neem oil solution by centrifugation. The hexane-neem oil solution was transferred to a 500 ml jacketed agitated vessel where the solution was heated to 165°F to remove the excess hexane. The recovered neem oil had a hexane content of 1%. The extracted neem oil was formulated into respective 1% and 3% solutions in 100 mls of water containing 1 drop of surfactant (Ivory™ Liquid). To test the effectiveness of these formulations, 25 potted chrysanthemum plants, cv. Iceberg, had all but 3 fully-expanded leaves removed. The plants were placed in a whitefly colony for 24 hours, removed, and sprayed with a water-mist to remove the adult whiteflies from the plants. The plants were divided into 5 groups of 5 and treated as follows:

Group 1) sprayed with water 0 days after exposure (DAE) to whiteflies,

Group 2) sprayed with 1% neem oil formulation 0 days after exposure to whiteflies,

Group 3) sprayed with 3% neem oil formulation 0 days after exposure to whiteflies,

Group 4) sprayed with 1% neem oil formulation 4 days after exposure to whiteflies, and

Group 5) sprayed with 3% neem oil formulation 4 days after exposure to whiteflies.

The greenhouse whitefly eggs usually hatched 5-6 days after oviposition, thus the 4 DAE treatments were applied

near the time of egg hatch. Once all the eggs had hatched on the control plants (those sprayed with water), the effectiveness of the oil fraction was assessed by counting the unhatched eggs and dead nymphs per leaf. The results were as follows:

Table 1

Effect of Neem Oil When Sprayed on New and 4-Day-Old Greenhouse Whitefly Eggs Laid on Chrysanthemums

Treatment	Eggs*	Dead Nymphs*	% Mortality**
Water	317ab	2c	0
1%, 0 DAE	185b	100bc	54
3%, 0 DAE	153b	143b	93
1%, 4 DAE	198ab	180b	90
3%, 4 DAE	360a	358a	99

* Values are means per 100 cm² leaf area. Means within trial followed by the same letter are not significantly different; DMRT, P = 0.05, N = 15 leaves.

** Number of dead nymphs divided by the number of eggs.

The extracted neem oil at both concentrations and exposure times caused significant nymphal mortality. It was observed that most nymphs died as they were emerging from the egg case. The extracted neem oil was most effective on the older eggs applied at a concentration of 3%.

Example 2

This example illustrates the effectiveness of extracted neem oil as a repellant to adult Bemisia tabaci whiteflies when sprayed on chrysanthemum foliage. The extracted neem oil was prepared and diluted into 1% and 3% formulation according to Example 1. To test the effectiveness of these formulations, nine 3-week-old potted chrysanthemum plants cv. Iceberg, having all but 3 fully expanded leaves removed, were divided into three groups of 3 and treated as follows:

Group 1) sprayed with water,

Group 2) sprayed with 1% neem oil formulation,

Group 3) sprayed with 3% neem oil formulation,

and then exposed to a colony of whiteflies for 24 hours. After exposure, the plants were cleaned of adult whiteflies and the number of eggs per leaf was determined. The results were as follows:

Table 2

Repellency of Neem Oils Against Bemisia tabaci on Chrysanthemums

Treatment	Eggs*
Water	110.0a
1%	18.0b
3%	0.0b

* Values are means calculated per 100 cm² leaf area. Means followed by the same letter are not significantly different; DMPT, P = 0.05, N = 9 leaves.

The results show that extracted neem oil is effective at repelling Bemisia whiteflies at both concentrations.

Example 4

This example illustrates the [illegible] action of hydrophobic-solvent extracted neem oil when sprayed on chrysanthemum foliage cv. Iceberg. Repellancy was quantified by counting the number of greenhouse whitefly (Trialeurodes vaporariorum) eggs laid on leaves. Neem oil formulations were prepared according to Example 1. Forty eight 3-4 week old chrysanthemum plants cv. Iceberg having all but 3 fully expanded leaves removed, were divided into three groups of 16 plants each and treated as follows:

Group 1) sprayed with water,
Group 2) sprayed with 1% neem oil formulation,
Group 3) sprayed with 3% neem oil formulation.

On the same day as spraying (Day 0) 4 plants from each group were placed in a whitefly colony for 24 hours. On days 3, 7 and 14, 4 more plants from each group were exposed to the whitefly colony for 24 hours. After each exposure, the number of eggs per 100 cm² of leaf area on the top 3 treated leaves were counted. The results were as follows:

Table 3

Neem Oils -- Residual Effects

Treatment	Mean No. Eggs/100 cm² Leaf Area*			
	Day 0	Day 3	Day 7	Day 14
Water	506a	844a	405a	72a
1%	69b	107b	14b	39ab
3%	18c	17b	1b	5b

*Means in same column followed by the same letter are not significantly different; DMRT, P=0.05, N=8 leaves.

The extracted neem oil formulations repelled ovipositing T. vaporariorum for up to 14 days after spraying. There were no clear differences in the level of repellancy between the 1% and 3% concentration, or the time between treatment and exposure.

Example 4

Control of Bean Rust by Extracted Neem Oil

Neem oil was extracted according to the procedure in Example 1. The extracted neem oil was mixed with water and diluted to 0.25, 0.5, and 1% and sprayed on the fully expanded primary leaves of beans cv. Pinto 111 until run off. The leaves were then inoculated with bean rust (Uromyces phaseoli) spores and placed in a dew chamber to allow infection. After approximately 16 hours the bean plants were removed from the dew chamber and placed in a greenhouse. After seven (7) days the number of rust pustules were counted. The results, in Table 4, show that the extracted neem oil is an effective foliar fungicide at these concentrations.

Table 4

Treatment	Pustules/100 cm^2*	% Control
Control	1174.4 a	0
0.25%	220.0 b	81.1
0.50%	116.6 b	90.2
1.00%	114.2 b	90.2

* Treatments with same letter are statistically similar; DMRT, P=0.05, N=6 leaves.

Example 5

Effect of Extracted Neem Oil and Margosan-O on the Repellancy of Whiteflies

Extracted neem oil as prepared in Example 1 was compared to Margosan-O a pesticide that contains the insect repellent azadirachtin. In these experiments 3 plants each were sprayed with water (control sample), a .8% solution of Margosan-O or a 2% solution of neem oil until run off. The plants were then placed in a chamber containing a colony of greenhouse whiteflies (Trialeurodes) for 2 hours. The plants were then removed from the chamber, the adults removed, and the number of eggs laid per cm^2 of leaf area counted. The results presented in Table 5 show that extracted neem oil is a much better repellent than Margosan-O for reducing egg laying by a factor of 6 compared to (Margosan-O the repellent) and by 45x over the control.

Table 5

Treatment	Eggs laid/cm^2 area*	Repellent Factor
Control	8.70 a	0
Margosan-O	1.13 b	7.7
Extracted Neem Oil	0.058 c	150

Example 6

Control of Mildew on Hydrangea

A solution of 2% extracted neem oil in water was sprayed on 5 hydrangias plants growing in greenhouse. The treated plants and an equal number of untreated plants were exposed to the natural mildew microrganisms found in the greenhouse for 6 weeks. At the end of this period the leaves of the plants were examined for mildew infestion. The untreated plants had an average of 46% of their leaves infested while the treated plants had 1.7% infestation.

Example 7

This example illustrates the potent ovicidal activity and repellent feeding deterrency of hydrophobic solvent extracts of neem seeds. Neem oil was extracted according to the procedure in example 1, and diluted with water and surfactant into 0.22%, 0.66% and 2.0% neem oil formulation. A series of tests were run on 6 types of insect eggs, both young and old including: Colorado potato beetle, tomato hornworm, housefly, Hawthorn lacebug, two-spotted spider mite, and greenhouse whitefly. The eggs were sprayed with water (as a control) and the 3 above neem oil formulations, and the number of hatching eggs was determined. The results were as follows:

Table VII

Ovicidal Activity of Neem Oil

Insect	Dose (%)	% Egg Mortality: Young Eggs	% Egg Mortality: Old Eggs
Colorado Potato Beetle	0	8	13
	0.22	81	9
Tomato Hornworm	0	8	16
	0.22	11	26
	0.66	46	42
	2	90	77
Hawthorn Lacebug	0	26	33
	0.22	30	39
	0.66	32	41
	2	75	69
Two-Spotted Mite	0	16	12
	0.22	54	33
	0.66	81	52
	2	90	95
Greenhouse Whitefly	0	6	12
	0.22	20*	27*
	0.66	30*	42*
	2	41*	49*

*All treated insects died after hatching.

As is clear from the above table, the 2% neem oil was effective at controlling hornworm, lacebugs, mites and whitefly eggs whether they were young or old. Young Colorado potato beetle eggs were effectively killed by 2% neem oil.

IN THE CLAIMS:

1. An insecticide and foliar fungicide comprising neem oil which is substantially free of azadirachtin and salannin, said neem oil prepared by:

a) extracting dried, coarsely ground neem seeds with a non-polar, hydrophobic solvent to obtain a neem oil extract,

b) removing the solvent to obtain the neem oil product.

2. An insecticide and foliar fungicide according to Claim 1 wherein the non-polar, hydrophobic solvent is selected from the group of pentane, hexane, heptane, octane, isooctane, decane, nonane, petroleum distillates, petroleum ether, cyclohexane, chlorobenzene, benzaldehyde, benezene, toluene, xylene, and mixtures thereof.

3. An insecticide and foliar fungicide according to Claim 1 wherein the neem oil product is diluted with 5 to 50% by volume of an emulsifying surfactant.

4. An insecticide and foliar fungicide according to Claim 1 wherein the neem oil product is diluted with 5 to 20% by volume of an emulsifying surfactant.

5. An insecticide and foliar fungicide according to Claim 1 wherein the neem oil product is diluted with 7 to 15% by volume of an emulsifying surfactant.

6. An insect ovicide comprising neem oil prepared accordingly to Claim 1.

7. An insecticide having larvicidal activity and insect repellancy comprising neem oil prepared according to Claim 1.

8. A fungicide for use on turf, horticultural and agricultural crops comprising neem oil prepared according to Claim 1.

9. An oviposition deterrent and repellant comprising neem oil according to Claim 1.

10. A method of controlling insect pests and fungi comprising contacting the insect or fungi with a neem oil formulation containing 0.1 to 10% neem oil which is substantially free of azadirachtin and salannin, 0.005 to 5% emulsifying surfactant and 0 to 99% water.

11. A method according to Claim 10 wherein the neem oil formulation contains 0.25 to 3% neem oil.

12. A method according to Claim 10 wherein the insect pests are selected from the group consisting of Colorado Potato beetle, Diamond Backed Moth, Whiteflies, leafminers, aphids, mealybug, hornworm, lacebug, mites, fleas, ticks, mosquitoes, and flies.

13. A method according to Claim 10 wherein the fungi are selected from the group consisting of mildews, rusts, leaf spots, dollar spots, brown patch and botrytis.